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W. A. Nierenberg
Director

Technical Report No. 25

Progress to Date in Deep Sound Channel Measurements of Ambient Noise

by

A. Berman and A. J. Saur

Research Sponsored by
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August 10, 1954

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PROGRESS TO DATE IN DEEP SOUND CHANNEL MEASUREMENTS OF AMBIENT NOISE

by

A. Berman and A. J. Saur

I. INTRODUCTION

It is well known that the speed of sound in sea water varies with temperature, salinity, and pressure. In regions where the composition of the water is not influenced by coastal run-off, the gradients of these quantities are vertical, or nearly so. Hence, the speed of sound in such regions is approximately a function only of depth. Except in the polar regions, the water temperature decreases with depth fairly rapidly until the temperature of maximum density is reached, and then very slowly so that maximum density is maintained with the increase of pressure. As a result, the speed of sound has a minimum at a depth of about 4000 feet in a large part of the North Atlantic. It is this minimum that produces the deep sound channel.

There is considerable interest in the characteristics of the ambient noise in the sound channel. On one hand, there is the question of the origin of ambient noise. Suppose, for example, that the important generators of noise are located in the surface of the ocean. Because of the "surface dipole effect" the sound from these generators would propagate downward with the results that (1) the noise in a given place would be determined by the surface configuration at that place, and (2) no variation in the noise with depth, except that produced by the attenuation of sound in water, would be observed. However, if distant sources which radiate horizontally were important in the generation of ambient noise, rather different effects could be expected. The noise would be independent of the state of affairs at the surface, and a pronounced variation with depth, both in overall intensity and in the fine structure of the power spectrum, would exist.

On the other hand, the sound channel has very interesting and promising possibilities as a means of communication, particularly between submerged submarines. This laboratory has undertaken the study of a possible submarine communication system utilizing a directional transducer suspended in the sound channel. Measurement of the ambient noise in the sound channel is a necessary step in estimating the power requirements and general feasibility of such a scheme.

A third reason for studying the variation of ambient noise with depth is that it is important information for the passive listening program. It is clear that sound generated by a ship can be propagated for great distances in the water only through the sound channel, and that this sound would be more intense in the sound channel than near the surface. If there were a region in the ocean where the ambient noise was nearly independent of depth, that region would be a suitable place for locating listening gear in the sound channel. If, however, the ambient noise in the sound channel were enough more intense than near the surface (or the bottom), the additional expense required to locate a hydrophone in the sound channel would not be worth-while.

Accordingly, this laboratory has begun a series of ambient noise measurements in the sound channel. The equipment used is a modification of the ship-borne gear described elsewhere by the present authors.[1] The changes in the equipment are necessitated by the requirement that the hydrophone of the present equipment be able to descend to depths of more than 5000 feet (see Section 2).

Through the cooperation of the U.S. Fish and Wildlife Service and the U.S. Hydrographic Office, the THEODORE N. GILL has been used as the listening ship in this work. To date, the measurements have been confined to the area in and around the Bahama Islands. A discussion of the stations and experimental results is given in Section 3.

It must be emphasized that this work is not complete and that more measurements are planned for the near future. The results quoted here are necessarily provisional. Any conclusions drawn are subject to revision or vitiation whenever more reliable data are available. The work will continue and a complete report will be issued at a later date.

II. APPARATUS

The apparatus used in this work is a modified version of the ship-borne ambient noise gear described in Reference 1. It consists of a neutrally buoyant hydrophone, or "duckling," a length of Signal Corps wire, type WD-1/TT, for bringing electrical signals from the duckling to the ship; an electrically powered winch with a reel having a capacity of ten miles of Signal Corps wire; and a set of recording equipment.

The duckling has been modified to withstand external pressures in excess of 2500 psi and to operate continuously on one set of batteries for at least 40 hours. The shell of this 2500 psi duckling consists of a 67 inch length of 5 inch aluminum pipe. The wall thickness is about 1/4 inch. A flange is welded to each end to accommodate the end plates. O-ring gaskets fit in grooves in the end plates to seal the assembled unit against water pressure. In addition to the end flanges, three other external flanges are welded at equally spaced intervals to the shell to strengthen it against collapsing under pressure.

Electrical signals are brought out through two seals mounted in the top plate. Each seal consists of a brass stud which threads into a brass cap. A lucite insulator separates the stud from the top plate. Two O-ring gaskets, one between the lucite insulator and the top plate, the other between the insulator and the brass cap, provide a pressure seal against sea water. The ends of the Signal Corps wire are inserted and clamped into Nicopress sleeves.* Each Nicopress sleeve has previously been silver-soldered to a special brass screw which also threads into the brass cap of the electrical seal. The splice thus formed is then wrapped with a special Simplex tape** and then with Scotch electrical tape No. 33.***

The internal circuitry of the 2500 psi duckling is similar to that of the units described in Reference 1. A new preamplifier circuit has been developed which employs subminiature tubes. This preamplifier is powered by a battery pack consisting of Mallory mercury cells.**** In addition to being lighter than the battery supply in former ducklings, this mercury cell battery pack has superior low temperature characteristics. Because of the low filament power required by the preamplifier, the 2500 psi duckling will operate continuously for at least 40 hours at 0° C on a set of batteries.

An effort has been made to incorporate temperature and pressure sensitive circuits in the 2500 psi duckling. The pressure circuit consists of a Giannini pressure transmitter***** and a battery.

*Supplier: National Telephone Supply Co., Cleveland, Ohio
**Supplier: Simplex Wire and Cable Corp., Cambridge, Mass.
***Supplier: Minnesota Mining and Mfg. Co., Richfield, N. J.
****Supplier: P. R. Mallory Co., Tarrytown, N. Y.
*****Supplier: G. M. Giannini Co., Springfield, N. J.

The temperature circuit consists of a thermistor, a dropping resistor, and a battery. In each case the temperature or pressure information is converted to a dc voltage. These two voltages are transmitted to the listening ship along the two conductors of the Signal Corps wire, with sea ground as a common return. The ambient noise signal is transmitted as an ac voltage along the same pair of conductors. Direct current meters on the listening ship are used to monitor the depth and temperature signals.

The temperature circuit is still in an experimental stage, and has not to date been satisfactorily reliable. Hence, it has been necessary to use Nansen bottle casts to determine accurately the temperature vs depth curve at each station.

The Signal Corps wire is carried on a winch, designed and built at this laboratory. The winch consists of a reel and level wind, driven through a chain reduction and a fluid coupling by a one horsepower dc motor. The fluid coupling is necessary to enable the winch to stall under heavy wire tension without breaking the Signal Corps wire or damaging the motor. The electrical signal from the wire is taken off the reel through a special mercury-brass slip ring.[2]

The recording apparatus is similar to that described in Reference 1. The amplifier has been modified to reduce its recovery time after overload from 90 seconds to about 5 seconds. The recording equipment is powered by a 1 kw rotary convertor, suspended by shock cord. Direct current power to the convertor is supplied by the battery bank on the GILL. A simple, manually controlled regulating circuit has been installed in the equipment to maintain the convertor output constant in frequency and voltage.

III. RESULTS

To date, the ambient noise group has made three cruises aboard the GILL. The procedure has been for the GILL to interrupt its regular oceanographic cruises at Nassau to permit loading the ambient noise equipment. The ambient noise cruises, each about a week in length, have thus been confined to the Bahamas. Ambient noise stations have been made in the Tongue of the Ocean, near New Providence Island, and in the Atlantic off Eleuthera and Great Abaco Islands. The stations are listed in Table I.

TABLE I

Ambient Noise Stations in the Bahamas

No.	Date	Approximate Hour (EST)	Latitude	Longitude	Maximum Hydrophone Depth-ft	Water Depth-ft
1	7 Oct '53	2400	24° 29'	77° 27'	5200	5700
2	8 Oct	1850	23° 59'	77° 19'	300	4740
3	9 Oct	0420	24° 53'	77° 36'	300	4800
4	9 Oct	0900	25° 1'	77° 39'	350	4800
5	27 Jan '54	1800	25° 33'	76° 19'	5400	15000
6	29 Jan	0600	25° 13'	77° 13'	600	6200
7	16 June	1900	26° 15'	76° 44'	4300	15000
	17 June	1500	26° 20'	76° 46'	4100	14000
8	18 June to 20 June	1930 0400	23° 41'	76° 50'	4500	4500

Except at Station 7, a Nansen bottle cast was made at each ambient noise station to determine temperature and salinity as a function of depth. No casts were made at Station 7 because extensive oceanographic data for that site were already available from measurements previously taken from the GILL.

From the Nansen cast data, a sound speed vs depth curve has been computed for each of the ambient noise stations. These curves are similar in that on each the minimum speed of sound occurs between 4000 and 4500 feet. A typical curve is shown in Fig. 1. This curve represents the sound speed profile at Station 7.

It is not the purpose of this report to present a complete summary of the data. Rather we show typical results. Two stations have been selected as typifying the various experimental conditions, namely, Stations 7 and 8.

Several drops were made at each station, with continuous recording of the noise signal as the duckling sank. The sinking rates were about 70 to 100 ft/min. In our previous work at depths of less than 1000 ft, it had been customary to use a sinking rate of 30 to 40 ft/min in order to use the falling as well as the hovering period of the duckling for recording. In carrying out the deep

measurements, we found that a faster sinking rate was advisable, both to insure that the hydrophone achieved a depth of 4000 to 5000 feet in a reasonable time as well as to obviate the wire tangles produced if the wire was too slack in the water for a long time. As might be expected, the ambient noise spectra corresponding to the falling periods exhibit more noise at frequencies below 100 cps than the spectra of the hovering periods.

Station 7 was located east of Great Abaco Island in 15,000 feet of water. There are no land masses east of this site. Hence, the ambient noise in the sound channel at this location can originate almost anywhere in the North Atlantic. The average power spectrum of the ambient noise at this station is shown in Fig. 2. This spectrum is an average of ten samples of the ambient noise recorded during the hovering periods of three drops. The hydrophone depth during these hovering periods varied from 3750 to 4150 feet. Over this range, there appears to be no systematic variation with depth of the ambient noise. There is, however, a considerable random variation in the spectrum, as indicated by the vertical lines in Fig. 2. Because of this large random variation, it is difficult, on the basis of the available data, to say whether or not a significant difference exists between the sound channel spectrum and the spectrum ordinarily observed near the surface.

Station 8 was located in the southern part of the Tongue of the Ocean. The Tongue of the Ocean is a body of deep water almost completely surrounded by islands and shoals. Any sound generated in the main body of the Atlantic or in the Caribbean cannot enter it except through reflections from the shore or transmission through the earth. One would expect, therefore, that ambient noise in the Tongue of the Ocean is primarily of local origin.

Power spectra of the data from three drops are shown in Figs. 3, 4, and 5. Figure 3 shows the spectrum observed with the hydrophone resting on the bottom. Figure 4 shows the result for the hydrophone at 3250 feet, and Fig. 5 for the hydrophone at 2800 feet. There is no significant variation apparent in these spectra. This uniformity with depth suggests that the ambient noise in the Tongue of the Ocean is generated at the surface and propagates downward.

Compared with the spectrum observed at Station 7, shown in Fig. 2, the levels observed at Station 8 are lower in the frequenvy range of 2 to 300 cps. If the data can be taken as reliable, this effect can be understood by the transmission properties of the sound channel. Very low frequency components -- below 2 cps,

corresponding to wave lengths of more than 2500 feet -- will diffract out of the sound channel and so will be rapidly attenuated. High frequency components of the noise will be lost through two mechanisms: (1) the more rapid attenuation of high frequency sound in sea water; (2) the tendency of high frequency sources, located in the surface, to radiate vertically, thereby precluding noise from such sources from being trapped in the sound channel.

IV. CONCLUSIONS

On the basis of the available data, the following conclusions are tentatively offered:

1. There is some evidence that in large, open bodies of water, such as the North Atlantic, a measurable fraction of the ambient noise is propagated in the sound channel. It is not possible at present to state whether any variation with depth exists in the noise spectrum in such bodies of water.

2. In enclosed bodies of water, such as the Tongue of the Ocean or a deep inland lake, the noise of nonbiological origin is probably generated at the surface.

3. The noise level in the sound channel is not great enough to preclude the use of the sound channel either for signaling between submerged, quiet submarines, or for passive listening for distant ships.

REFERENCES

1. Saur, A. J., and Berman, A. Investigation of ocean ambient noise at low frequencies; Part I - Instrumentation and analytic methods. Columbia University, Hudson Laboratories, Technical report no. 19. February 15, 1954.

2. Berman, A., Saur, A. J., and McMahon, B. Mercury contact slip rings for low-level signal applications. Columbia University, Hudson Laboratories, Contribution no. 5. The Review of Scientific Instruments. 25:399. April, 1954.

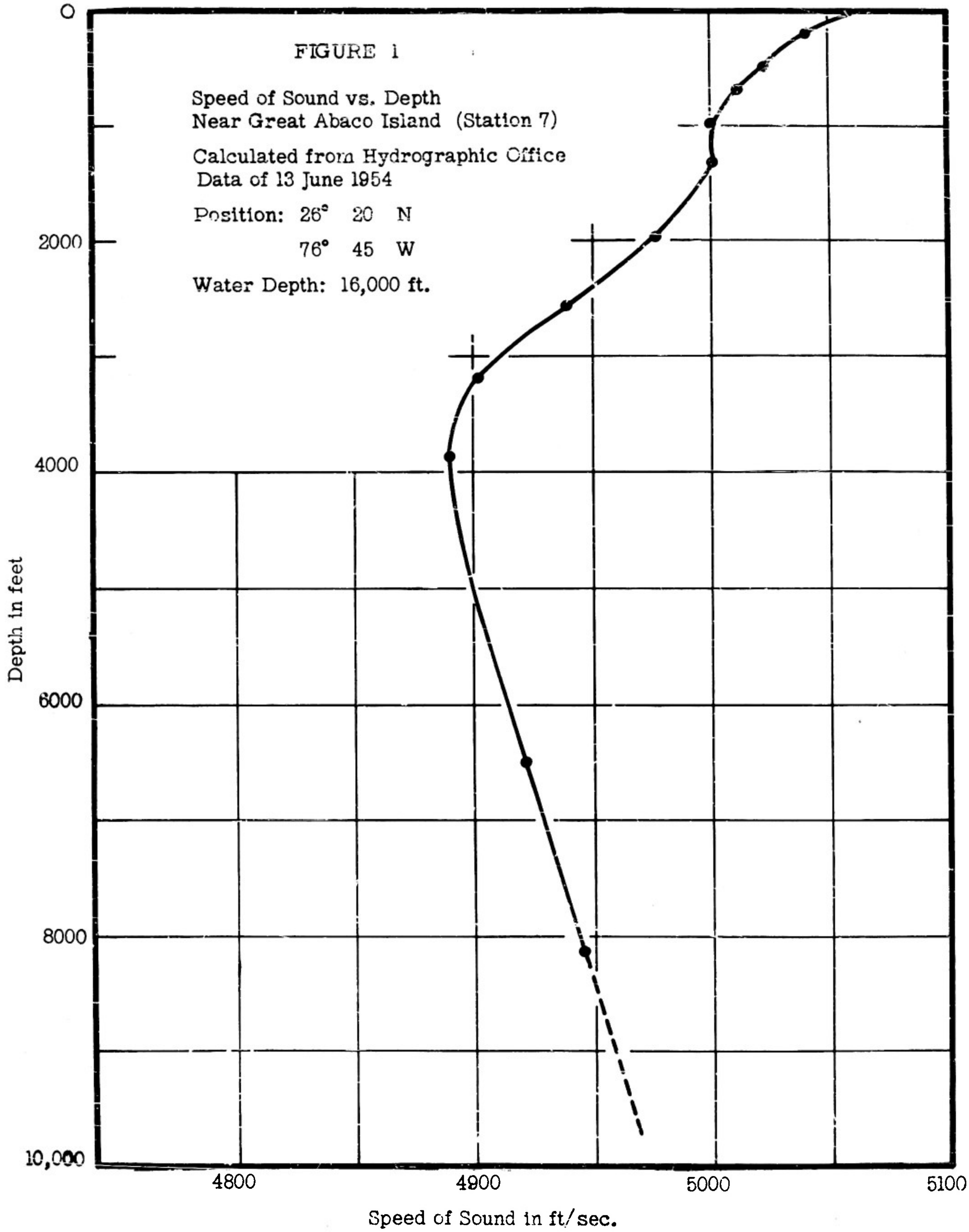
FIGURE 1
Speed of Sound vs. Depth
Near Great Abaco Island (Station 7)
Calculated from Hydrographic Office
Data of 13 June 1954
Position: 26° 20 N
76° 45 W
Water Depth: 16,000 ft.
0
2000
4000
6000
8000
10,000
Depth in feet
4800
4900
5000
5100
Speed of Sound in ft/sec.

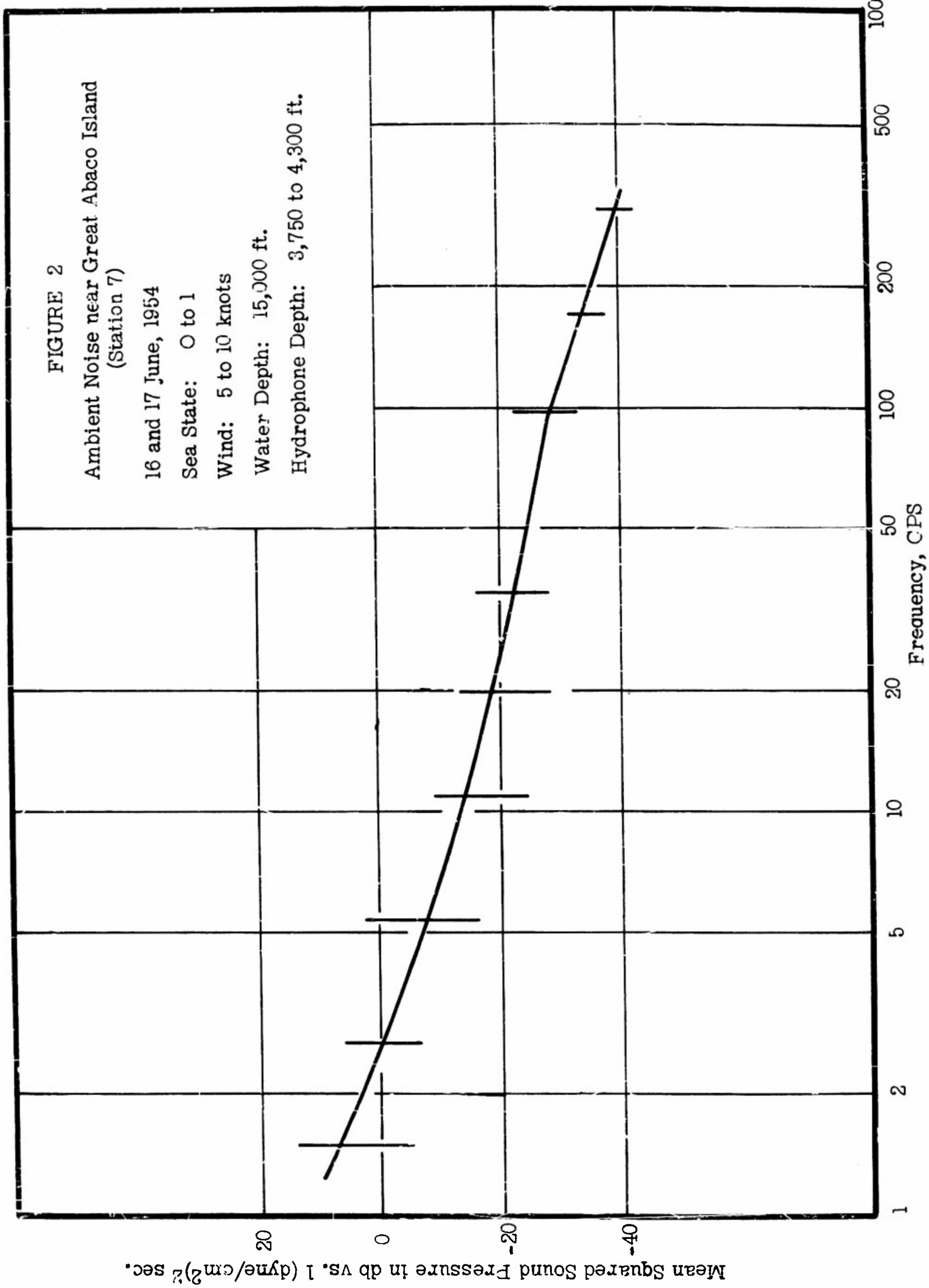

FIGURE 2
Ambient Noise near Great Abaco Island
(Station 7)

16 and 17 June, 1954

Sea State: 0 to 1

Wind: 5 to 10 knots

Water Depth: 15,000 ft.

Hydrophone Depth: 3,750 to 4,300 ft.

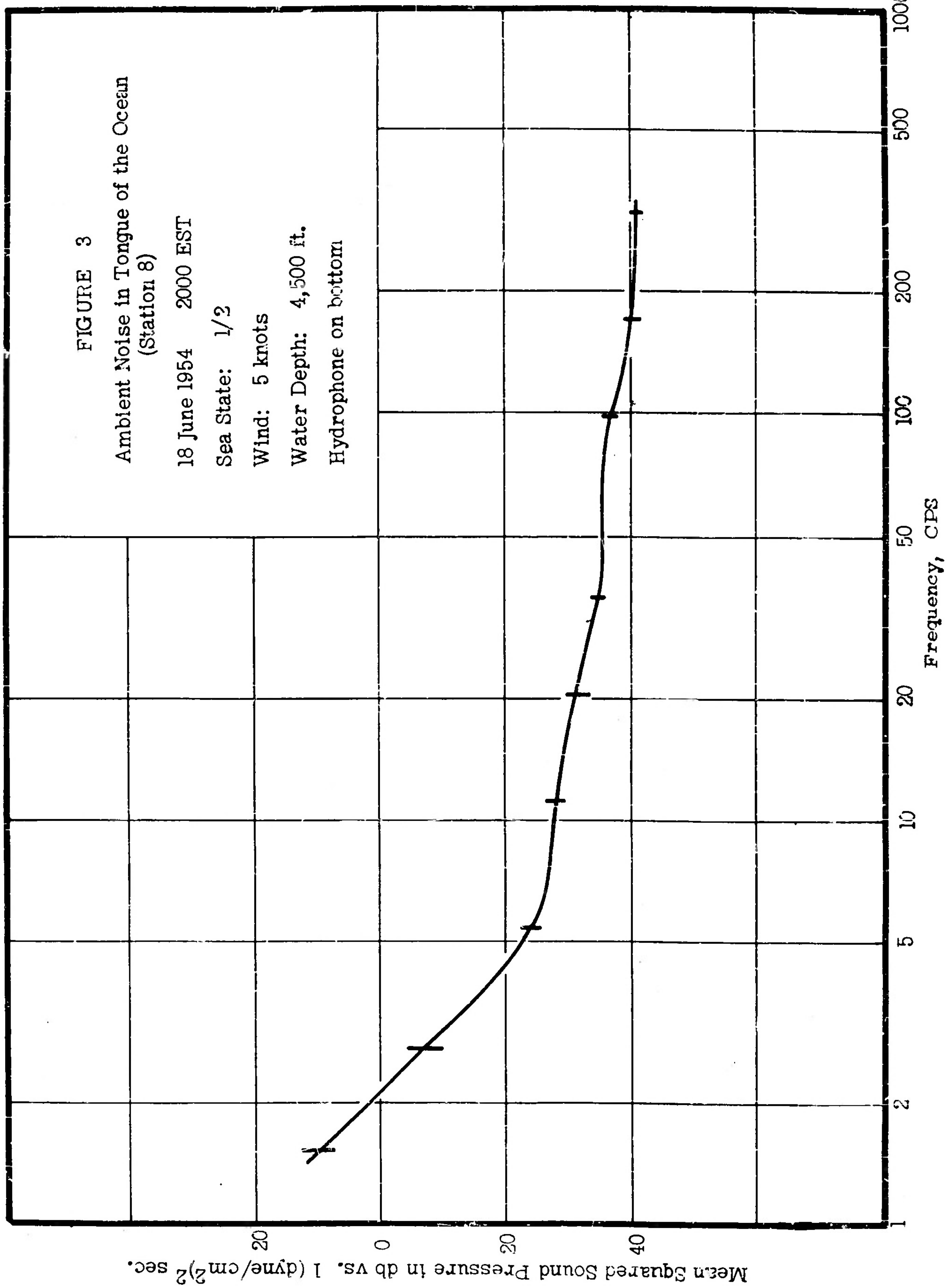
FIGURE 3
Ambient Noise in Tongue of the Ocean
(Station 8)
18 June 1954 2000 EST
Sea State: 1/2
Wind: 5 knots
Water Depth: 4,500 ft.
Hydrophone on bottom
1
2
5
10
20
50
100
200
500
1000
Frequency, CPS
20
0
20
40
Mean Squared Sound Pressure in db vs. 1 (dyne/cm2)2 sec.

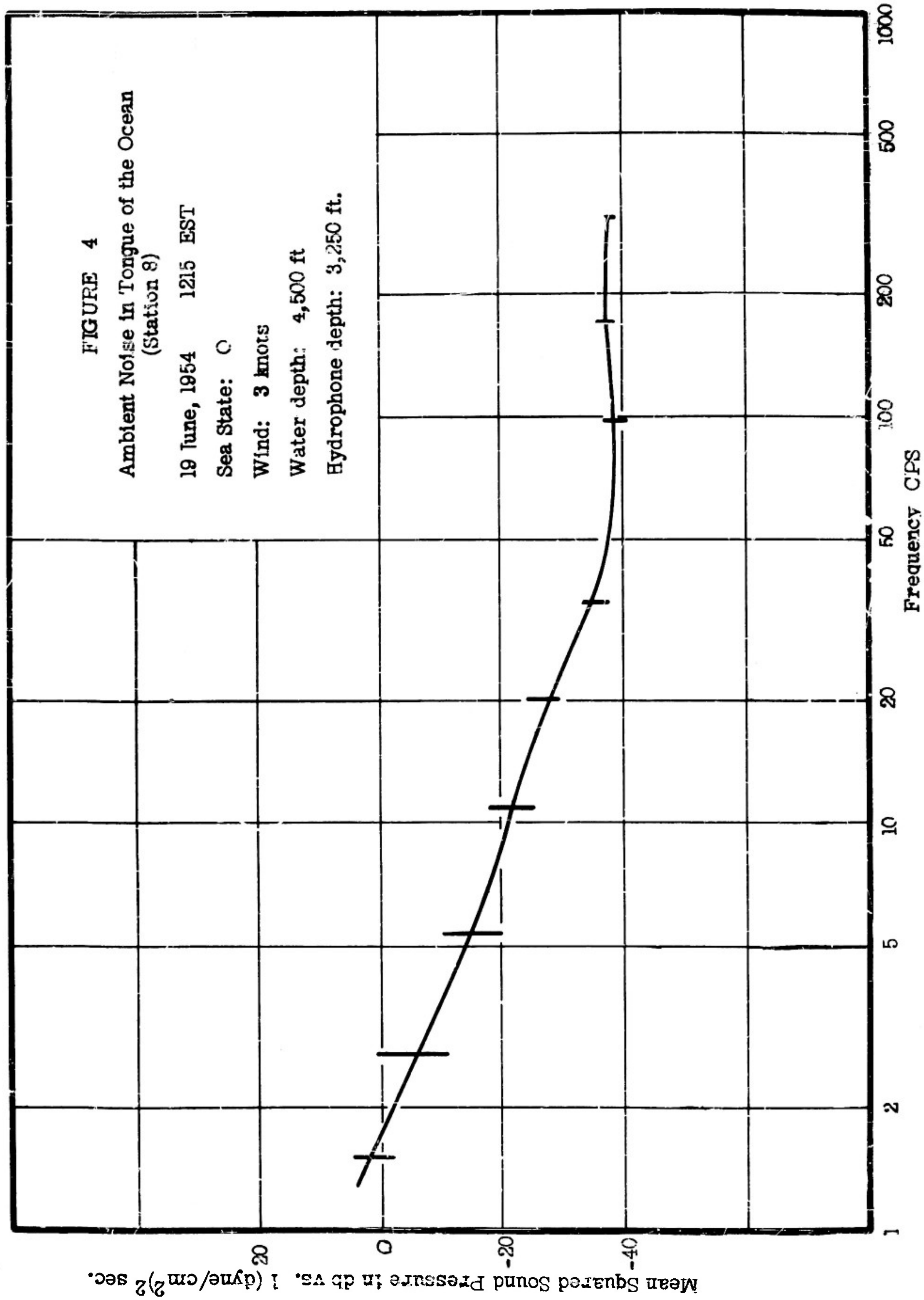

FIGURE 4

Ambient Noise in Tongue of the Ocean (Station 8)

19 June, 1954 1215 EST

Sea State: 0

Wind: 3 knots

Water depth: 4,500 ft

Hydrophone depth: 3,250 ft.

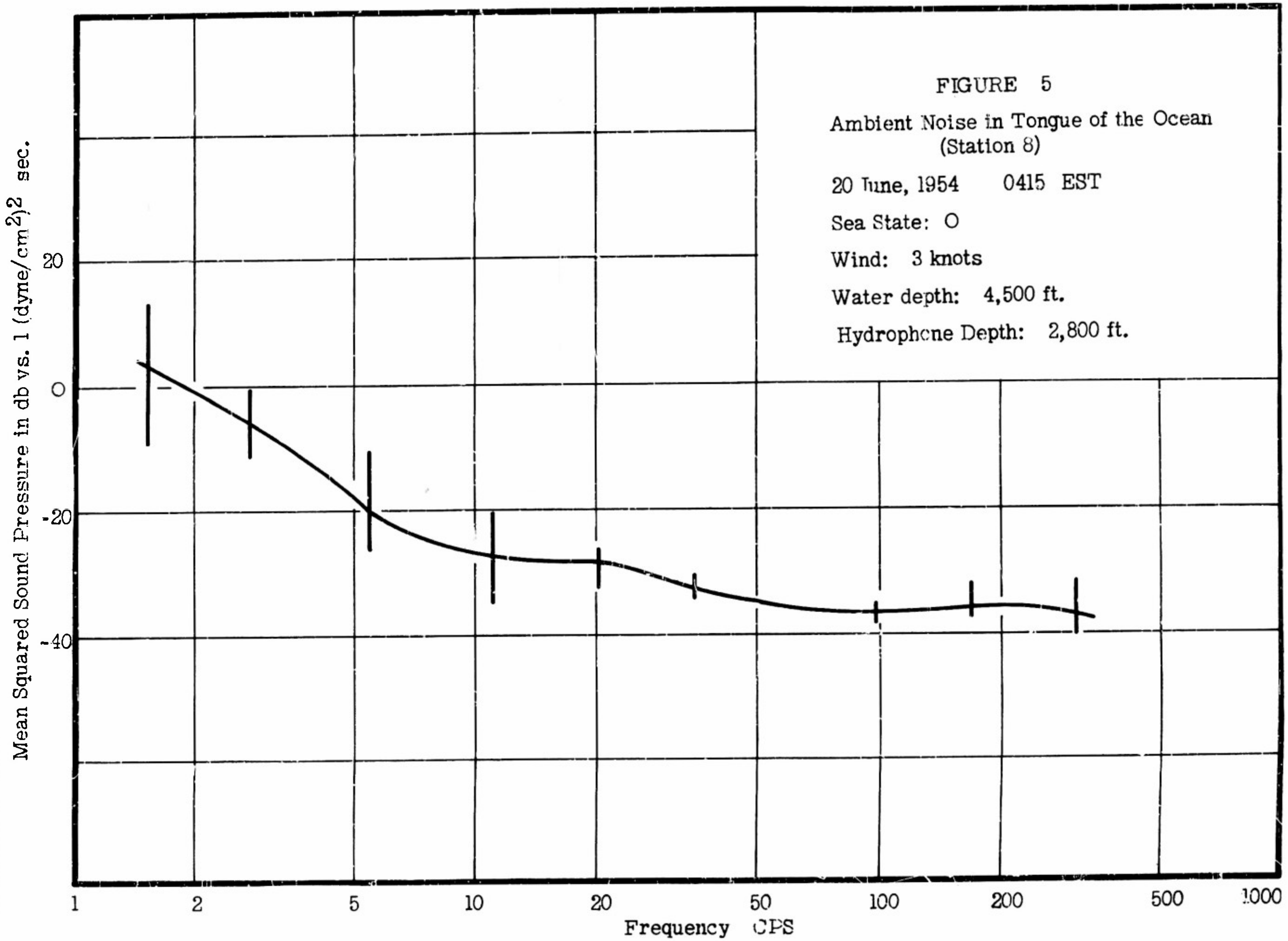

FIGURE 5

Ambient Noise in Tongue of the Ocean (Station 8)

20 June, 1954 0415 EST

Sea State: O

Wind: 3 knots

Water depth: 4,500 ft.

Hydrophone Depth: 2,800 ft.

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